IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Applicant:	§	
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Boxman et al.	§	Confirmation No. 8087
	§	
Serial No.: 10/615,141	§	
	§	
Filed: July 9, 2003	§	Group Art Unit: 1753
	§	
For: Method and Apparatus for Producing Nanostructures	§	Attorney Docket: 27/216
	§	
Examiner: Kishor Mayekar	§	

Commissioner for Patents
Alexandria, Virginia 22313-1450

AFFIDAVIT OF RAYMOND REUVEN BOXMAN UNDER 37 CFR 1.132

I am presently employed as a Professor of Electrical and Electronics Engineering at Tel-Aviv University, Tel-Aviv, Israel. I received my BS and MS degrees from the Massachusetts Institute of Technology (MIT) in 1969, and my Ph.D. degree from M.I.T. in 1973, all in Electrical Engineering. In 1989 I was named a Fellow of the Institute of Electrical and Electronics Engineers. I was awarded the Boris and Renee Joffe Award, by the International Union for Electrodeposition and Surface Finishing (1984) and the Walter Dyke Award, by the Permanent International Scientific Committee of the International Symposia on Discharges and Electrical Insulation in Vacuum (2000). In 2006, I was named the incumbent of the Kranzberg Chair in Plasma Engineering at Tel-Aviv University. At Tel-Aviv University I have served as Head of the Materials Engineering Program from 1999 to 2006, and Chairman of the Department of Interdisciplinary Studies 1984-1986 and again from 2004 until the present time.

I have authored or co-authored over 160 papers, journal articles, and publications, most of which relate to plasma and electrical discharges, or their use in material processing. Exemplary publications include:

1. A. Moshkovith, V. Perfiliev, D. Gindin, N. Parkansky, R. Boxman, L. Rapoport, "Surface texturing using pulsed air arc treatment" Wear (2007) doi:10.1016/j.wear.2006.11.043.
2. N. Parkansky, G. Frenkel, B. Alterkop, R.L. Boxman, S. Goldsmith, Z. Barkay, Yu. Rosenberg and O. Goldstein, "Influence of pulsed arc parameters on powder production in ethanol", Powder Technology 162 (2): 121-125 Mar 1, 2006.
3. N. Parkansky, O. Goldstein, B. Alterkop, R.L. Boxman, Z. Barkay, Yu. Rosenberg and G. Frenkel, "Features of micro and nano-particles produced by pulsed arc submerged in ethanol", Powder Technology 161 (3): 215-219 Feb. 3, 2006
4. N. Parkansky, B. Alterkop, R.L. Boxman, S. Goldsmith, Z. Barkay, Y Lereah, "Pulsed discharge production of nano- and micro-particles in ethanol and their characterization" Powder Technology Vol. 150 (2005) pp. 36-41.
5. N Parkansky, R L Boxman, B Alterkop, I. Zontag, Y Lereah, Z Barkay, "Single-Pulse Arc Production of Carbon Nanotubes in Ambient Air" J. Phys. D: Appl. Phys. Vol. 37, pp 2715-19, 2004.

I have also co-edited a book on Electrical arcs in vacuum: R.L. Boxman, P. Martin, D. Sanders (editors), *Handbook of Vacuum Arc Science and Technology*, Noyes Publications (Park Ridge, NJ) 1995.

My statement follows on page 2; my resume starts on page 7; and a relevant article entitled: "Single-pulse arc production of carbon nanotubes in ambient air" is appended to this affidavit, starting on page 32.

I have examined Patent application no. 10/615,141 of Boxman et al., as well as Patent nos. 6,759024 and 5,482,601 to Takikawa and Ohshima, respectively.

I would like to clarify that the term "pulse", as commonly used in the art with respect to conventional DC or AC power supplies, refers to generally short pulses, which are usually produced by special pulse circuits. These pulses contrast sharply with the application of DC or AC electrical excitation for longer periods, e.g. a few seconds, which is usually accomplished by switching on, and then off, a suitable DC or AD power supply, respectively.

Short Pulses

Our invention is distinguished from the prior art of both Ohshima and Takikawa in that we teach the use of short pulses (<1 ms), while Ohshima teaches the use only of DC excitation, and Takikawa primarily teaches the use of DC and DC excitation, but mentions also "pulses" of up to 3 s duration. I contend that such long "pulses" are fundamentally different from the short pulses in the instant invention, both because of the technology involved in producing them, and the effect which they achieve.

Relatively long "pulses", i.e. of a few seconds duration, are typically produced by merely manually switching on and then off a conventional DC or AC power supply. In contrast, short pulses, i.e. pulses of less than 1 ms, and especially short pulses in the preferred duration range of 0.2-20 μs, are more economically produced by special pulse circuits, in which energy is first stored in a capacitor or inductor, and then discharged into the plasma load at some predetermined time.

Secondly, the use of short pulses taught in the instant invention, and especially pulses with durations in the preferred range of 0.2-20 μs, was found by the inventors to be particularly advantageous in the production of carbon nanotubes (CNTs). The

motivation for trying this range of pulse durations stems from the inventors' insightful analysis of the results of one of Takikawa's scientific publications, as indicated in the specification of the instant invention: "Takikawa, et al. examined the cathode spot track left on a graphite cathode by a 50 Amp, 1.5 second duration arc, driven in the retrograde direction by a 4 mT magnetic field in a 0.5 Pa He gas background. SEM examination of the arc track revealed the presence of numerous multi-walled CNTs at the last location of the cathode spot, but nowhere else. This suggests that the cathode spot sequentially produced CNTs, and then destroyed them, as the cathode spot moved along the surface at approximately 3 millimeters per second, leaving undestroyed CNTs only at the last cathode spot location. See H. Takikawa, Y. Tao, R. Miyano, T. Sakakibara, X. Zhao, and Y. Ando, Jpn. J. Appl. Phys. 40, 2001, 3414-8."

The inventors' analysis of this result suggested that if the arc were excited with a short pulse, perhaps CNTs would be formed, but there would be insufficient time for the cathode spot of the arc to subsequently destroy the formed CNTs. Furthermore, assuming a cathode spot diameter of d=3 μm, and using the cited cathode spot velocity of v=3 mm/s, the preferred pulse duration T should be shorter than the time required for the spot to move one diameter, i.e. $T<d/v=1$ ms. It should be pointed out that cathode spots "move" by being spontaneously extinguished after a random period of time, whose average value may be termed the cathode spot lifetime Tcs. Re-ignition of the cathode spots occurs at an adjacent location, thus giving the appearance of movement. A preferred pulse time would be on the order of magnitude of the spot lifetime, which is typically in the ns-μs range.

This reasoning was verified by experimental work carried out in the inventors' laboratory, reported both in the instant specification and in subsequent publications. In one such work, Y. Zontag showed in his MS thesis "Single-pulse arc production of

carbon nanotubes in ambient air" (submitted to Tel Aviv University in October 2005, in Hebrew), that as the pulse duration was lengthened from 7 to 12μs and then to 32 μs, the density of the CNTs increased from ρ=0.01 to 0.1 to 10 per μm^2, while the typical CNT length was relatively unchanged in the first step, but drastically decreased in the second step, from 11-28 μm to 0.5-0.8 μm. Thus the time length of the pulse plays a critical role in determining the density and length of the CNTs. In a potential application for CNTs, namely as electron emitters, it would be advantageous to have long CNTs, such that their field enhancement factor will be maximal, and a spacing l=ρ-1/2 approximately equal to the CNT length, such that there will be many emitters, but that they will not shield the electric field from their neighbor. These above data suggests that these parameters can be achieved in the pulse duration range indicated in the instant specification.

Furthermore, and quite significantly, by using considerably shorter pulses, the selectablility of localizing nanotube placement is enabled—as taught in the instant specification and in an independent claim.

Deposition of CNTs on a Ni or other Metallic Workpiece

Takikawa teaches that the workpiece upon which the CNTs are deposited must contain carbon. In contrast, in one embodiment of the instant invention, CNTs were deposited on Ni workpieces, not containing carbon. In the specification of the instant invention, Table 1, items 15 and 16, it is shown that CNTs were probably produced on Ni workpieces (which did not contain carbon). At the time the instant patent application was filed, diagnostic tools available to the inventors were insufficient to conclude with absolute certainty that CNTs were produced under these circumstances. Subsequently the inventors, having better diagnostic tools, were able to verify that CNTs can be produced on Ni workpieces (i.e. with C present in the workpiece).

Scientific results to this effect were published by the inventors in:

N Parkansky, R L Boxman, B Alterkop, I. Zontag, Y Lereah, Z Barkay, "Single-Pulse Arc Production of Carbon Nanotubes in Ambient Air" J. Phys. D: Appl. Phys. Vol. 37, pp 2715-19, 2004, which is appended to this affidavit.

I declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further, that these statements with the knowledge that the making of willfully false statements and the like is punishable by fine or imprisonment, or both, under section 1001 of Title 18 of the United States Code, and may jeopardize the validity of any patent issuing from this patent application.

17 May 2007

DATE

Raymond Reuven Boxman

RAYMOND L. BOXMAN

CURRICULUM VITAE

March 2007

Date of Birth:	June 9, 1946
Place of Birth:	Philadelphia, PA
Family Status:	Married, four children
Military:	Capt., Signal Corp., U.S. Army Reserve. R.O.T.C. 9/64 - 6/68 Commissioned 6/68. Active Duty for Training 2/73 - 5/73, Ft. Gordon, Ga. (Signal Officers Basic Course). Seren (Res.) IAF

EDUCATION:

Summer, 1963	Microbiology course, sponsored by National Science Foundation at La Salle College, Philadelphia, PA.
February 1969	S.M., S.B., in Electrical Engineering, Massachusetts Institute of Technology. Besides course in E.E., studied electives in physics & nuclear engineering. In co-op program with General Electric Co. Elected to following honorary societies: Eta Kappa Nu, Tau Beta Pi, and Sigma Xi. Thesis Title: Triggered Vacuum Interrupters . Thesis Supervisor: G.L. Wilson.
February, 1973	Ph.D., Massachusetts Institute of Technology, Department of Electrical Engineering. Major: Electromagnetic Fields & Matter, with emphasis on plasma physics. Minor: Bio-Electronics. Thesis Title: Interferometric Measurement of Electron & Vapor Densities in a High Current Vacuum Arc . Thesis Supervisor: G.L. Wilson.

EXPERIENCE:

Summers 1963,'64,'65	METROMEDIA INC, Radio Station WIP, Philadelphia, PA. *Radio Engineer* – Duties included production of on-the-air show and remotely controlling two transmitters.
June - Sept 1966	GENERAL ELECTRIC CO. Missile & Space Div., Philadelphia, PA. *Co-op Student* - Aided in development of miniaturized capacitance type pressure transducer for space applications. Designed electronic signal processor for transducer. Experience in feedback and control, bridge circuits, transducers, operational amplifiers, telemetry systems, and integrated circuits.
Feb - June 1967	RESEARCH LABORATORY OF ELECTRONICS (M.I.T.), Cambridge, *MA. Student* - Developed scheme for measuring diamagnetism of after glow beam discharge plasma. Scheme compensated for magnetic flux diffusion through metal vessel, and for generator noise in the imposed magnetic field.

RAYMOND LEON BOXMAN, Ph.D.

June - Sept 1967	GENERAL ELECTRIC CO., Missile and Space Div., Valley Forge, PA. *Co-op Student* - Conducted research on utilizing positive column of plasma glow discharge to simulate re-entry plasma conditions, and their effect on microwave transmission.
Feb - Sept 1968	GENERAL ELECTRIC CO., Power Transmission Div., Philadelphia, PA. *Research Engineer*, (co-op assignment) - Conducted research on triggered vacuum interrupters, a device for switching high power electrical currents. Investigated effects of contact and trigger voltages, circuit, trigger material, contact separation and magnetic field on triggering characteristics. Studied photographs of arc, waveshapes, and device parts to propose triggering theory. Experience in metal vapor arcs, pulse circuits, vacuum technology, high speed photography, and material processing. Research formed basis for Master's thesis.
1968 - 1970	M.I.T. , Cambridge, MA. *Teaching Assistant* - Conducted classes, tutorials, demonstrations and graded papers in third and fourth year courses in electromagnetics, electromechanics, and signals and systems analysis. Graded papers in graduate courses in plasma dynamics and microwave circuits.
June-Sept 1969	REHOBOTH INSTRUMENTS LTD , Rehoboth, Israel. Conducted feasibility study of use of SEC television system for recording x- ray crystallography data for computer analysis.
1970 - 1971	MAGNETIC CORPORATION OF AMERICA , Cambridge, MA. *Consultant* - aided in feasibility study of M.H.D. power generation for a particular application.
1970-1973	ELECTRIC POWER SYSTEMS ENGINEERING LABORATORY (M.I.T.) , Cambridge, MA. *Research Assistant* - Conducted research which formed basis for Ph.D. thesis. Duties included design of vacuum chamber, laser, interferometer, vibration isolation system and pulse circuits. Measured electron & copper vapor densities by infrared and optical interferometry in a copper vapor arc such as those which occur in vacuum switches. Supervised undergraduate laboratory and thesis projects.
1973-1975	GENERAL ELECTRIC CO. Power Delivery Group, Philadelphia, PA. *Sr. Research Engineer* – Conducted development projects in vacuum circuit breakers & research in metal vapor arcs. Research included measuring anode surface temperature during anode spot formation by spectral radiometry, theoretical analysis of anode spot formation mechanisms, and studying the motion of high current vacuum arcs in magnetic fields.
1975 to present	TEL AVIV UNIVERSITY, School of Engineering, Dept. of Interdisciplinary Studies. *Professor of Electrical and Electronic Engineering* - Instruct courses in electromagnetic theory, circuits, lasers, thin films, technical writing and electrical discharges in gases. Conduct research and supervise graduate student research in electrical discharge physics and applications, and metallurgical and thin film coatings.
1979 to present	*Consultant* - Consultant on coatings, thin films, plasmas and electrical discharge applications.

RAYMOND LEON BOXMAN, Ph.D.

Sept.1981 - June 1982	UNIVERSITY OF SOUTH CAROLINA, Dept. of Electrical and Computer Engineering. *Visiting Associate Professor* - Instructed undergraduate course in engineering analysis, and graduate courses on electrical discharges. Graduate course on experimental techniques in plasma research presented state-wide via the USC television system. Conducted research and advised graduate students on electrical breakdown in vacuum in the USC High Voltage Laboratory.
July-August 1982	BROWN BOVERI RESEARCH CENTER , Baden, Switzerland, *Visiting Scientist* - Advised on the framing, organization, set-up, and initiation of a coordinated experimental and theoretical research program on vacuum arc phenomena relevant in vacuum switchgear.
1989-1990	DREXEL UNIVERSITY , Philadelphia, PA, *Visiting Professor of Electrical and Computer Engineering* - Instructed graduate course on thin film technology and undergraduate courses in electromagnetic fields. Initiated research program on using vacuum arc deposition to produce high temperature superconducting films.
July-August 1995	MULTI-ARC INC. Rockaway, N.J., *Guest Scientist* - Conducted research on diamond-like carbon coatings.

MEMBERSHIPS:

- Fellow of the Institute of Electrical & Electronics Engineers and the IEEE Nuclear & Plasma Sciences Society
- Society of Sigma Xi
- Israel Vacuum Society
- Israel Plasma Science and Technology Society

PROFESSIONAL AND UNIVERSITY ACTIVITIES:

October 1982	Publicity chairman and coordinator for video tape publication of invited lectures for the Xth International Symposium on Discharges and Electrical Insulation in Vacuum. (Columbia SC).
Sept. 1983	Editor for vacuum arcs for special issue of the IEEE Transactions on Plasma Science entitled "Vacuum Discharge Plasmas".
June 1983	Editor for vacuum arcs for special issue of IEEE Transactions on Electrical Insulation entitled "Insulation and Breakdown in Vacuum".
1981/2	While abroad on sabbatical, gave invited seminars on various vacuum arc topics at the State University of New York at Buffalo, University of Minnesota, Calor-Emag Company (Federal Republic of Germany), Westinghouse Research and Development Center, and the Oak Ridge National Laboratory.
1983	University administrative responsibility has included serving on engineering faculty computer committee, and on the executive committee of the university safety council. Chaired ad-hoc faculty committee for setting up infrastructure for VAX computers.
1984-86	Head, Department of Interdisciplinary Studies.
1986-1989	Faculty graduate education committee.
1990-1992	Faculty electrical engineering curriculum committee.
1986	Organizing committee chairman of the XIIth International Symposium on Discharges and Electrical Insulation in Vacuum and proceedings editor.

October 1987	Guest Editor, IEEE Transactions on Plasma Science, special issue on Vacuum Discharge Plasmas.
February 1988	Guest Editor, IEEE Transactions on Electrical Insulation, special issue on Insulation and Breakdown in Vacuum.
1988-	Member of the Permanent International Scientific Committee of the International Symposia on Discharges and Electrical Insulation in Vacuum. Secretary 1988-1994. Chairman - Awards Committee, 1989-1993.
1988 -2006	Associate Editor, IEEE Transactions on Plasma Science.
December, 1990	Guest Editor, special issue of IEEE Transactions on Plasma Science on "Plasma Deposition".
1990-2004	Member of the Hard Coatings and Vapor Deposition Technology Symposium Committee, Int. Conf. on Metallurgical Coatings and Thin Films.
1993-1996	Faculty of Engineering graduate education committee
1993-2000	TAU appointments and promotions committee, for the Center for Technological Education (Holon).
1995-2000	TAU equipment committee.
1996-98	Faculty of Engineering computer committee
1997-2001	Founder and First Chairman, Israel Plasma Science and Technology Society
1999-	Member of the Editorial Board, Plasma Chemistry and Plasma Processing
2000-2002	Chairman, Faculty of Engineering M.Sc. Committee
1999-	Head, Faculty of Engineering Materials Engineering Program
2002-3	Chairman, *ad hoc* committee investigating Faculty of Engineering organization
2002-4	Member, Tel Aviv University M.Sc. Committee
Feb 2004	Chairman, 7th Israeli Conference on Plasma Science and Applications
Oct 2004 -	Chairman, Department of Interdisciplinary Studies, School of Electrical Engineering
Oct 2004 -	Chairman, Faculty of Engineering Research Committee
Feb 2006	Chairman, International Conference on Superhard Coatings

Honors :

October 1984	Boris and Renee Joffe Award, presented by the International Union for Electrodeposition and Surface Finishing at the 11th World Congress on Metal Finishing (Interfinish '84).
January 1989	Fellow of the Institute of Electrical and Electronics Engineers, for "Advances in Vacuum Arc Theory and its Applications".
September 2000	Walter Dyke Award, by the Permanent International Scientific Committee of the International Symposia on Discharges and Electrical Insulation in Vacuum, for "his outstanding body of work in the field of electrical discharges in vacuum, in particular for his contributions to the physics, technology, and applications of vacuum arc plasmas".

RAYMOND LEON BOXMAN, Ph.D.

LIST OF PUBLICATIONS.

Articles in Journals

1. R.L. Boxman, "Interferometric Measurement of Electron and Vapor Densities in a High-Current Vacuum Arc," Journal of Applied Physics, Vol. 45, pp. 4835-484 6, 1974.
2. R.L. Boxman, "Measurement of Anode Surface Temperature During a High Current Vacuum Arc," Journal of Applied Physics, Vol. 46, pp. 4701-4704, 1975.
3. R.L. Boxman, "Magnetic Constriction Effects in High-Current Vacuum Arcs Prior to the Release of Anode Vapor," Journal of Applied Physics, Vol. 48, pp. 2338-2345, 1977.
4. R.L. Boxman, "High Current Vacuum Arc Column Motion on Rail Electrodes," Journal of Applied Physics, Vol. 48, pp. 1885-1890, 1977.
5. R.L. Boxman, "Triggering Mechanisms in Triggered Vacuum Gaps," IEEE Trans. Electron Devices, Vol. ED-24, 122-128, 1977.
6. R.L. Boxman, J.H. Harris, and A. Bless, "Time Dependence of Anode Spot Formation Threshold Current in Vacuum Arcs," IEEE Trans. Plasma Science, Vol. PS-6, pp. 233-238, 1978.
7. R.L. Boxman and M.L. Sloan, "A Scanning Technique for Obtaining Linear Fringe Shift Readout from a High Resolution Interferometer," Applied Optics, Vol. 17, pp. 2794-2797, 1978.
8. R.L. Boxman and D.J. Shlien, "Interferometric Technique for Measuring the Refractive Index Variation of a Liquid with Temperature," Review of Scientific Instruments, Vol. 49, pp. 861-863, 1978.
9. R.L. Boxman and D.J. Shlien, "Interferometric Measurement Technique for the Temperature Field of Axisymmetric Buoyant Phenomena," Applied Optics, Vol. 17, pp. 2788-2793, 1978.
10. D.J. Shlien and R.L. Boxman, "Temperature Field Measurement of an Axisymmetric Laminar Plume," Phys. Fluids, Vol. 22, pp. 631-634. 1979.
11. D.J. Shlien and R.L. Boxman, "Laminar Starting Plume Temperature Field Measurement," Int. J. Heat and Mass Transfer, Vol. 24, pp. 919-931, 1981.
12. R.L. Boxman and S. Goldsmith, "Excited State Densities in a Multi-Cathode-Spot Al Vacuum Arc., I. Spectroscopic Measurements," Journal of Applied Physics, Vol. 51, pp. 3644-3656, 1980.
13. S. Goldsmith and R.L. Boxman, "Excited State Densities in a Multi-Cathode-Spot Al Vacuum Arc, II. Theoretical Approach" Journal of Applied Physics, Vol. 51, pp. 3657-3663, 1980.
14. V.A. Finch, R. Dmiel, R. Boxman, A. Shkolnik and C. Taylor, "Why Black Goats in Hot Deserts? Effects of Coat Color on Heat Exchange of Wild and Domestic Goats," Physiol. Zool. Vol. 53, pp. 19-25, Jan 1980.
15. R.L. Boxman and S. Goldsmith, "The Interaction Between Plasma and Macroparticles in a Multi-Cathode-Spot Vacuum Arc", Journal of Applied Physics, Vol. 52, pp. 151-162, 1981.
16. R.L. Boxman, E. Gerby and S. Goldsmith, "Behavior of High-Current Vacuum Arc Between Hollow Cylindrical Electrodes in a Radial Magnetic Field," IEEE Trans. Plasma Sci. (Special Issue on Arc Plasmas) Vol. PS-8, pp. 308-313, 1980.
17. S. Goldsmith, S. Shalev, and R.L. Boxman, "Excited State Densities in a Multi-Cathode-Spot Cd Vacuum Arc," Physica, Vol. 104C, pp. 107-115, 1981.
18. S. Shalev, S. Goldsmith and R.L. Boxman, "Population Inversion of Cd^+ Excited-States in the Plasma of Cadmium Vapor Vacuum Arc," IEEE J. Quant. El., Vol. QE-17, pp. 8-10, 1981.
19. S. Goldsmith and R.L. Boxman, "Coulomb Approximation Calculations of Transition Probabilities in the Transition Array $3d^9 4d - 3d^4 4f$ in Cu II", J. Phys. B: Atom. Molec. Phys. Vol. 14, pp. 3031-3036, 1981.

20. R. L. Boxman and S. Goldsmith, "A Model of the Anode Region in a Uniform Multi-Cathode-Spot Vacuum Arc", Journal of Applied Physics, Vol. 54, pp. 592-602, 1983.
21. S. Shalev, S. Goldsmith, and R.L. Boxman, "Absorption Effects of the Cd II 4416 A Line in a Cadmium Vacuum Arc Plasma", Journal of Applied Physics, Vol. 53, pp. 6736-6741, 1982.
22. F.T. Warren, J.M. Wilson, J.E. Thompson, R.L. Boxman, and T. Sudarshan, "Vacuum Switch Trigger Delay Characteristics", IEEE Trans. Plasma Sci. (special issue on Plasma Switching), PS-10, pp. 298-301, 1982.
23. J.M. Wilson, R.L. Boxman, and J.E. Thompson, "Breakdown Time of a Triggered Vacuum and Low-Pressure Switch", IEEE Trans. Electrical Insulation Vol. EI-18, pp. 238-242, 1983.
24. R. L. Boxman, S. Goldsmith, I. Izraeli, and S. Shalev, "A Model of the Multi-Cathode-Spot Vacuum Arc", IEEE Trans. Plasma Sci. Vol. PS-11, pp. 138-145, 1983.
25. S. Goldsmith, S. Shalev and R.L. Boxman, "Anode Melting in a Multi Cathode-Spot Vacuum Arc", IEEE Trans. Plasma Sci., Vol. PS-11, pp. 127-132, 1983.
26. S. Shalev, S. Goldsmith and R.L. Boxman, "In-situ Determination of Macroparticles Velocity in a Copper Vacuum Arc", IEEE Trans. Plasma Sci., Vol. PS-11, pp. 146-151, 1983.
27. I. Izraeli, S. Goldsmith and R.L. Boxman, "The Influence of the Self Magnetic-Field on the Steady State Current Distribution in an Axially Flowing Conducting Medium", IEEE Trans. Plasma Sci. Vol. PS-11, pp. 160-164, 1983.
28. F.T. Warren, R.L. Boxman, J.E. Thompson and T. Sudarshan, "Current Evolution in a Pulsed Overstressed Radial Vacuum Gap", IEEE Trans. Electrical Insulation, Vol. EI-18, pp. 226-229, 1983.
29. R. Lee, T. Sudarshan, J.E. Thompson, G.R. Nagabhoshana and R.L. Boxman, "Predischarge Current Measurement in Vacuum Gaps Bridged with Plexiglass Insulators", IEEE Trans. Electrical Insulation, Vol. EI-18, pp. 280-286, 1983.
30. S. Goldsmith, Y. Bresler and R.L. Boxman, "Spectroscopic Study of Excited-State Densities in a Zn Vacuum-Arc Plasma", Journal of Applied Physics, Vol. 54, pp. 5691-5697, 1983.
31. S. Shalev, S. Goldsmith, R. Boxman, S. Einav, A. Avidor, "Laser Doppler Annenometry: A method for measuring macroparticle dynamics in vacuum arcs", J. Phys. E: Scientific Instruments, Vol. 17, pp. 56-61, 1984.
32. S. Shalev, R.L. Boxman, S. Goldsmith, "Velocities & Emission Rates of Cathode Produced Molybdenum Macroparticles in a Vacuum Arc". Journal of Applied Physics, Vol. 58, pp. 2503-2507, 1985.
33. I. Israeli, A. Whitman, R.L. Boxman and S. Goldsmith, "Asymptotic Analysis of the Steady State Current Flow in a Uniform Multi-Cathode-Spot Generated Vacuum Arc Plasma Flow". IEEE Trans. Plasma Science, Vol. PS-13, pp. 281-284, 1985.
34. B. Gellert, E. Schade and R.L. Boxman, "Time and Spatially Resolved Spectroscopy of the Plasma State Prior to and During Anode Spot Formation in High Current Vacuum Arcs". IEEE Trans. Plasma Science, Vol. PS-13, pp. 265-268, 1985.
35. S. Shalev, R.L. Boxman and S. Goldsmith, "Macroparticle Dynamics During Multi-Cathode-Spot Vacuum Arcs". IEEE Trans. Plasma Science, Vol. PS 14, pp. 59-62, 1986.
36. R.L. Boxman, S. Goldsmith, S. Shalev, H. Yaloz and N. Brosh, "Fast Depositions of Metallurgical Coatings and Production of Surface Alloys Using a Pulsed High Current Vacuum Arc". Thin Solid Films, Vol. 139, pp. 41-52, 1986.
37. G. Disatnik, R.L. Boxman, S. Goldsmith, "Characteristics of macro particle emission from a high current density multi-cathode-spot pulsed vacuum arc", IEEE Trans. Plasma Sci., Vol. PS-15, pp. 520-523, 1987.
38. S. Goldsmith, R.L. Boxman, E. Sapir, Y. Cohen, H. Yaloz, N. Brosh, "Distribution of peak temperature and energy flux on the surface of the anode in a multi-cathode-spot pulsed vacuum arc", IEEE Trans.Plasma Sci., Vol. PS- 15, pp. 510-514, 1987.

39. I. Izraeli, R.L. Boxman, S. Goldsmith, "The current distribution and the magnetic pressure profile in a vacuum arc subjected to an axial magnetic field", IEEE Trans. Plasma Sci., Vol. PS-15, pp. 502-505, 1987.
40. S. Bababeygy, R.L. Boxman, S. Goldsmith, "Corrosion evaluation of very rapid high-current vacuum arc coatings", IEEE Trans. Plasma Sci., Vol. PS-15, pp. 599-602, 1987.
41. R.L. Boxman and S. Goldsmith, "Cathode-spot arc coatings: physics, deposition and heating rates, and some examples", Surface and Coatings Technology, Vol. 33, pp. 153-167, 1987.
42. Y. Cohen, R.L. Boxman and S. Goldsmith, "Angular distribution of ion current emerging from an aperture anode in a vacuum arc", IEEE Trans. Plasma Sci., Vol. PS-17, pp. 713-716, 1989.
43. R.L. Boxman and S. Goldsmith, "A model for a uniform steady-state vacuum arc with a hot anode", IEEE Trans. Plasma Sci., Vol. PS-17, pp. 661-665, 1989.
44. R.L. Boxman and S. Goldsmith, "Principles and applications of vacuum arc coatings", IEEE Trans. Plasma Sci., Vol. PS-17, pp. 705-712,1989.
45. R. Rosenbaum, M. Ben-Shlomo, S. Goldsmith and R.L. Boxman, "Low temperature electronic transport properties of W, Mo, Ta and Zr thin films", Phys. Rev. *B* . Vol. 39, pp. 10009-10019, 1989.
46. U. Ghera, R.L. Boxman, S. Ruschin and H. Kleinman, "Laser induced electron source in a vacuum diode", Journal of Applied Physics, Vol. 66, pp. 4425-4430, 1989.
47. R.L. Boxman and S. Goldsmith, "Momentum interchange between cathode spot plasma jets and background gases and vapors and its implication on vacuum arc anode spot development", IEEE Trans. Plasma Sci. Vol. PS-18, pp. 231-236, 1990.
48. R.L. Boxman and S. Goldsmith, "Characterization of a 1 kA vacuum arc plasma gun for use as a metal vapor deposition source", Surface and Coatings Technology, Vol. 43/44, pp. 1024-1034, 1990.
49. R.L. Boxman and S. Goldsmith, "Macroparticle Contamination in Cathodic Arc Coatings: Generation, Transport, and Control", Surface and Coatings Technology, Vol. 52, pp. 39-50, 1992.
50. A. Ben-Shalom, R.L. Boxman and S. Goldsmith, "Ion current collected at various distances and argon background pressures in a copper vacuum arc", IEEE Trans. Plasma Sci. Vol. 21, pp. 435-439, 1993.
51. N. Parkansky, I. Beilis, R.L. Boxman and S. Goldsmith, "Electrode erosion during pulsed arcing", IEEE Trans. Plasma Sci. Vol. 21, pp. 458-462, 1993.
52. R.L. Boxman and S. Goldsmith, "Mass and surface conductivity gain on polymer surfaces metalized using vacuum arc deposition", Thin Solid Films, Vol. 236, pp. 341-346, 1993.
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